



## FREE-STANDING AND ALIGNED CARBON NANOTUBES AND SYNTHESIS THEREOF

This application claims the benefit of U.S. Provisional Patent Application Serial No. 60/089,965, filed June 19, 1998, and U.S. Provisional Patent Application Serial  
5 No. 60/099,708, filed September 10, 1998.

This invention was made through the support of the U.S. Army Research Office (Grant No. DAAG55-97-1-0139). The Federal Government may retain certain rights in the invention.

### FIELD OF THE INVENTION

10 The present invention relates to a product with a substrate having one or more carbon nanotubes, a method of producing that product, and devices utilizing the product.

### BACKGROUND OF THE INVENTION

15 Since the first observation of carbon nanotubes, numerous papers have reported studies on the yield of well-graphitized nanotubes, their diameter and wall thickness (single or multiple), growth mechanisms, alignment, electron emission properties, nanodevices, theoretical predictions, and potential applications. Selective positioning and growth of carbon nanotubes is necessary for future integration with conventional microelectronics as well as the development of novel devices. However,  
20 limited progress has been reported in the controlled placement of nanotubes. Alignment of the carbon nanotubes is particularly important to enable both fundamental studies and applications, such as cold-cathode flat panel displays, chargeable batteries, and vacuum microelectronics.

Specifically, vertical alignment has been an important goal due to its  
25 technological importance for applications such as scanning probe microscopy and field emission flat panel displays. Attempts to manipulate nanotubes for these applications have been made by post-growth methods such as cutting a polymer resin-nanotube composite, or drawing a nanotube-ethanol suspension through a ceramic filter. Because these techniques are difficult and labor intensive, *in situ* aligning of nanotubes during